PATENT ABSTRACTS OF JAPAN

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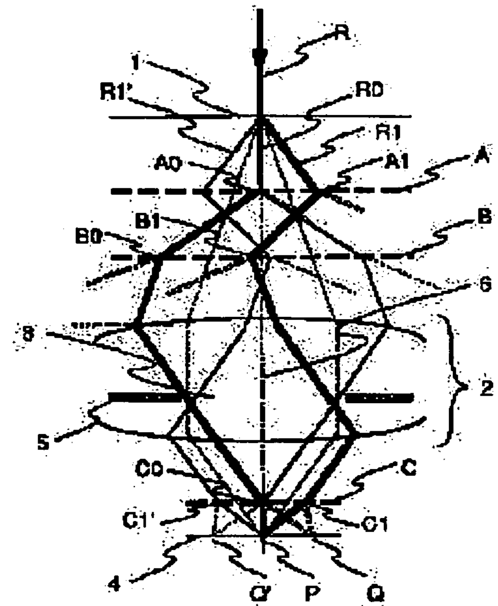
(54) METHOD AND APPARATUS FOR PROJECTION EXPOSING

(57)Abstract:
PURPOSE: To improve the resolution exceeding the diffraction limit by emitting the light from a light source to a mask, diffracting the pattern of the mask, diffracting the diffracted light through a projection optical system, and reproducing the pattern on a sample to be exposed.
CONSTITUTION: A mask 1 is inserted between a projection optical system 2 and diffraction gratings A, B, and a diffraction grating C is inserted between the system 2 and a wafer 4. In this case, the gratings A, B, C are simultaneously phase gratings. The light R perpendicularly incident to the mask 1 is diffracted to zero order diffracted light R0, + primary diffraction light R1 and − primary diffracted light R1' on the mask surface. The light R0 arrives at a point A0 on the grating A, and the light diffracted in the − primary direction is diffracted to + primary direction at the point B0 on the grating B. Thereafter, it is diffracted at the point C0 on the grating C via the left end of the pupil 3 in ± primary direction, and arrived at two points Q, P on the image surfaces.



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CLAIMS

[Claim(s)]
[Claim 1] The projection exposure approach characterized by consisting of the process for which a mask is prepared, the process which irradiates the light from the light source at the above-mentioned mask, the process which diffracts the pattern of the above-mentioned mask, and the process which diffracts the this diffracted light through a projection optical system, and reproduces and exposes the above-mentioned mask pattern on a sample.
[Claim 2] The projection exposure approach according to claim 1 characterized by diffracting twice as the above-mentioned process which carries out diffraction.
[Claim 3] the light source, the 1st and the 2nd diffraction means irradiates the pattern on a mask with the light from this light source, and diffract the light from this mask, the projection optical system that project the diffracted light on a sample, and the 3rd diffraction means which diffracts the light from this projection optical system -- this -- the projection aligner characterized by to consist of a sample base in which the sample arranged under the 3rd diffraction means lays.
[Claim 4] The above 1st and the 2nd diffraction means are a projection aligner according to claim 3 characterized by being a phase grating.
[Claim 5] In the approach of forming a pattern on the above-mentioned substrate by irradiating at a mask the light of the wavelength lambda which emitted the light source through an illumination-light study system, and carrying out image formation of the pattern on the above-mentioned mask to up to a substrate according to the projection optical system of numerical aperture NA and reduction percentage M:1 So that it may have the 1st parallel diffraction grating with the above-mentioned substrate between the above-mentioned substrate and the above-mentioned projection optical system and the image of a mask pattern may be reproduced by interference of the light diffracted by said 1st diffraction grating near the substrate side The projection exposure approach characterized by preparing the diffraction grating, the 2nd diffraction grating and the 3rd diffraction grating, of two sheets sequentially from the above-mentioned mask side at the above-mentioned mask and parallel between the above-mentioned mask and the above-mentioned illumination-light study system.
[Claim 6] The projection exposure approach according to claim 5 characterized by the cutoff spatial frequency f of the optical system which prepared said diffraction grating being larger than the cutoff spatial frequency f0 of the optical system which does not prepare said diffraction grating, and being 2 double less or equal of f0.
[Claim 7] The space period P1 of said 1st diffraction grating is the projection exposure approach according to claim 5 characterized by being in the range of lambda/(1.42, NA) <=P1 <= lambda/NA.
[Claim 8] It is the projection exposure approach according to claim 5 characterized by the periodic direction of the 1st, 2nd, and 3rd diffraction gratings of the above being equal, and the space period P1 of the 1st diffraction grating of the above, the space period P2 of the 2nd diffraction grating, and the space period P3 of the 3rd diffraction grating filling the relation of about 1/P 3= 1/P2-1/(M-P1).
[Claim 9] It is the projection exposure approach according to claim 5 characterized by optical paths Z2 and Z3 filling /P2= (Z3-/M+Z1andM) / relation of P1 mostly (Z3-Z2) from an optical path Z1 and the above-mentioned mask front face of the 2nd and 3rd diffraction grating of the above from the above-mentioned substrate front face of the 1st diffraction grating of the above.
[Claim 10] Each installation location of the 1st diffraction grating of the above, the 2nd diffraction grating of the above, and the 3rd diffraction grating of the above, The thickness of each transparence substrate which prepares the 1st diffraction grating of the above, the 2nd diffraction grating of the above, and the 3rd diffraction grating of the above, And the projection exposure approach according to claim 5 characterized by

setting up the period of the 2nd diffraction grating of the above according to the physical relationship of NA of said projection optical system and a cutback scale factor, and the each diffraction grating and the above-mentioned substrate so that the aberration between the above-mentioned mask side and the image surface may serve as min.
[Claim 11] The space period P2 of said 2nd diffraction grating is P2 <=1/(1-2 and NA/M).
******** -- the projection exposure approach according to claim 5 characterized by things.
[Claim 12] Said 2nd and 3rd diffraction gratings are the projection exposure approaches according to claim 5 characterized by being a phase grating.
[Claim 13] Said 1st diffraction grating is the projection exposure approach according to claim 5 characterized by being a phase grating.
[Claim 14] Between said substrate and said 1st diffraction grating, the width of face to said one direction by below Z1 and NA While a space period prepares the about 2, Z1, and 1st [of NA] protection-from-light pattern [whether the protection-from-light pattern of the above 1st on a mask and the 2nd protection-from-light pattern which shades a field / **** / almost / are prepared in right above / of said mask /, or directly under, and an exposure field is restricted to it, and] Or the projection exposure approach according to claim 5 characterized by scanning and exposing on a substrate the exposure field by which the limit was carried out [above-mentioned], or exposing, moving in the shape of a step.
[Claim 15] Said diffraction grating is the projection exposure approach according to claim 5 which is a 1-dimensional diffraction grating and is characterized by carrying out aberration amendment so that the wave aberration of said projection optical system may serve as axial symmetry centering on the diameter of a direction vertical to the periodic direction of the above-mentioned diffraction grating on a pupil.
[Claim 16] Said mask is the projection exposure approach according to claim 5 characterized by including a periodic mold phase shift mask.
[Claim 17] Said mask is the projection exposure approach according to claim 5 characterized by having a detailed pattern in the specific direction according to said the 1st period and direction of a diffraction grating.
[Claim 18] Said mask is the projection exposure approach according to claim 5 characterized by amending a pattern configuration according to said the 1st period and direction of a diffraction grating.
[Claim 19] The projection exposure approach according to claim 5 characterized by for the refractive index n having filled between said 1st diffraction grating and said substrates with the larger liquid than 1, and setting NA of said projection optical system as the range of 0.5<NA<n/2.
[Claim 20] In the projection aligner which has the projection optical system of the numerical aperture NA which carries out image formation of the pattern on the above-mentioned mask to the illumination-light study system which irradiates the light of the wavelength lambda which emitted the light source at the mask on a mask stage near the substrate front face on a substrate stage, and reduction percentage M:1 It has the 1st diffraction grating of the above-mentioned substrate and 1st parallel space period P1 (lambda/(1.42, NA) <=P1 <= lambda/NA) between the above-mentioned substrate and the above-mentioned projection optical system. So that the image of a mask pattern may be reproduced by interference of the light diffracted by the 1st diffraction grating of the above near the substrate side The projection aligner characterized by having the diffraction grating, the 2nd diffraction grating and the 3rd diffraction grating, of two sheets sequentially from the above-mentioned mask side in the above-mentioned mask and parallel between the above-mentioned mask and the above-mentioned illumination-light study system.
[Claim 21] It is the projection aligner according to claim 20 characterized by the periodic direction of the 1st, 2nd, and 3rd diffraction gratings of the above being equal, and the space period P1 of the 1st diffraction grating of the above, the space period P2 of the 2nd diffraction grating, and the space period P3 of the 3rd diffraction grating filling the relation between 1/P3=1 / (M-P1) +1/P2 mostly.
[Claim 22] Each installation location of the 1st diffraction grating of the above, the 2nd diffraction grating of the above, and the 3rd diffraction grating of the above, The thickness of each transparence substrate which prepares the 1st diffraction grating of the above, the 2nd diffraction grating of the above, and the 3rd diffraction grating of the above, And the projection aligner according to claim 20 characterized by setting up the period of the 2nd diffraction grating of the above according to the physical relationship of NA of said projection optical system and a cutback scale factor, and the each diffraction grating and the above-mentioned substrate so that the aberration between the above-mentioned mask side and the image surface may serve as min.
[Claim 23] The projection aligner according to claim 20 characterized by having the function exposed while the width of face to said one direction scans and exposes on a substrate the exposure field which a space

period has the protection-from-light pattern of 2 and NA-Z1 mostly, or was restricted with the above-mentioned protection-from-light pattern by below Z1 and NA or moves in the shape of a step between said substrate and said 1st diffraction grating.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the pattern formation approach for forming the detailed pattern of various solid-state components, and the projection aligner used for this.
[0002]
[Description of the Prior Art] In order to improve the degree of integration and working speeds of a solid-state component, such as LSI, detailed-ization of a circuit pattern is progressing. Moreover, detailed-ization of a pattern is desired for improvement in a property, such as light and electronic devices, such as laser, and various kinds of quantum effectiveness components, a dielectric, a magnetic-substance component. The reduced-projection-exposure method excellent in mass production nature and definition ability is widely used for such pattern formation now. Since the resolution limit of this approach is proportional to exposure wavelength and in inverse proportion to the numerical aperture (NA) of a projection lens, improvement in the resolution limit has been performed by short-wavelength-izing and high NA-ization.
[0003] Moreover, the various image improving methods, such as a phase shift method, deformation illumination (oblique incidence illumination), and the pupil filter method, are applied as technique for improving the resolution of a reduced-projection-exposure method further. these will use the engine performance of optical system for theoretical until [diffraction marginal (cutoff spatial frequency = 2 NA/lambda) last-minute] validity conventionally The these images improving method (often called a super resolution method) is discussed by the 49th page (the Science forum company **, 1994, Tokyo) from innovation of a ULSI lithography technique, Chapter 1, and the 34th page, for example.
[0004] On the other hand, some methods of expanding the spatial-frequency band of optical system are learned as an approach of improving the resolution of a microscope across the conventional above-mentioned diffraction limitation. These spatial-frequency band dilation is discussed by the 859th page (1968) from application physics, the 37th volume, No. 9, and the 853rd page, for example. One of approaches of this scans two grid patterns, keeping conjugation relation mutual right above [of a body and an image] (at least inside of the depth of focus), they form a moire pattern by superposition of a body and the 1st grid pattern of the right above of it, and get over by passing a lens system and piling up this moire pattern with the 2nd grid pattern by the image side. Since a moire pattern has spatial frequency lower than a body and the 1st grid pattern, it can pass a lens system. It applies for applying this approach to a reduced-projection-exposure method. Generally, since it is difficult, it is operating scanning a grid pattern mechanically right above [wafer] as a grid by preparing a phot chromics material directly on a wafer, and scanning an interference fringe in piles to this.
[0005]
[Problem(s) to be Solved by the Invention] however, the above -- there are the following technical problems in various conventional techniques.
[0006] As for short-wavelength-izing of exposure light, ArF excimer laser (wavelength of 193nm) is first considered to be a limitation from the problem of the permeability of an optical (lens) ingredient. Moreover, as for NA of a projection optical system, 0.6-0.7 are considered to be limitations from the problem on a lens design and manufacture. However, the resolution limit of the exposing method is 0.3 lambda/NA extent, when 0.5 lambda/NA and a periodic mold phase shift method are generally used, therefore even if it uses the limitation of the above-mentioned short-wavelength-izing and a raise in NA, a pattern 0.1 micrometers or less is conventionally difficult for formation. Moreover, by the describing [above] periodic mold phase shift method, since a mask pattern is restricted, a actual limit size retreats further about a more common circuit pattern. Moreover, although amplification of exposure area is demanded with large-scale-izing of

LSI, it is very difficult to satisfy simultaneously amplification of the exposure field of a projection optical system, and the demand of a raise in NA.

[0007] On the other hand, the various spatial-frequency band dilation aiming at crossing the conventional diffraction limitation aims at expanding a minute body for a microscope. For this reason, there was a trouble that it was not necessarily suitable in forming the minute optical image demanded by optical lithography. For example, by the approach of using said moire pattern, the device or optical system for scanning two grids, keeping conjugation relation mutual right above [of a mask and a wafer] becomes it is remarkable and complicated. Since exposure of a resist is substantially performed with EBANESSENTO light, there are problems, like it becomes difficult for light to decline in a wavelength range and to expose a thick resist. Furthermore, even when using phot clo MIKKU, there is no suitable ingredient. Therefore, when mass production method of LSI was considered, there was a trouble that it could not necessarily be said that it is practical.

[0008] The object of this invention is in the projection exposing method which forms the detailed pattern of various solid-state components to offer the approach of improving the resolution across the conventional diffraction limitation (cutoff spatial frequency). Specifically, it is in offering the new projection exposure approach that effectiveness almost equivalent to having doubled [a maximum of] the NA substantially is acquired, and the aligner which makes this possible, without changing NA of a projection optical system.

[0009] Another object of this invention is to offer the projection exposure approach of having been suitable for mass production method of LSI which is simultaneously satisfied only with adding some amelioration to these of the big exposure field and high resolution possible [the thing of the improvement effectiveness in resolution to acquire], without changing greatly the configuration and optical system of an aligner of a conventional type.

[0010]

[Means for Solving the Problem] In case image formation of the above-mentioned object is carried out to up to a substrate using the light of wavelength lambda according to the projection optical system (numerical aperture = NA, reduction percentage =1:M) of MASUKUPATAN ** and a pattern is formed, between the above-mentioned substrate and the above-mentioned projection optical system While preparing the 1st diffraction grating of the space period P1 (however, it is desirable that it is lambda/(1.42, NA) <=P1 <= lambda/NA) in the above-mentioned substrate and parallel So that the image of a mask pattern may be reproduced by interference of the light diffracted by the 1st diffraction grating of the above near the substrate side It is attained by preparing the diffraction grating, the 2nd diffraction grating and the 3rd diffraction grating, of two sheets sequentially from the above-mentioned mask side between said projection optical systems and said masks at the above-mentioned mask and parallel.

[0011] In order to reproduce the image of a mask pattern faithfully by the diffracted light of the 1st diffraction grating, the periodic direction of the 1st, 2nd, and 3rd diffraction gratings of the above is equal, and the space period P1 of the 1st diffraction grating of the above, the space period P2 of the 2nd diffraction grating, and the space period P3 of the 3rd diffraction grating are set up so that the relation of about 1/P 3= 1/P2-1/(M-P1) may be filled. Moreover, the optical path Z1 from the above-mentioned substrate front face of the 1st diffraction grating of the above and the optical paths Z2 and Z3 from the above-mentioned mask front face of the 2nd and 3rd diffraction grating of the above are set up so that /P2= (Z3-/M+Z1andM) / relation of P1 may be filled mostly (Z3-Z2). Furthermore, it is desirable that it is P2<=1/(1-2 and NA/M). Moreover, it is desirable to set up the thickness of the installation location of the 1st, 2nd, and 3rd diffraction grating and the transparence substrate of each diffraction grating and the period of the 2nd diffraction grating so that the aberration between the above-mentioned mask side and the image surface may serve as min. Moreover, it is desirable that a space period prepares the 2nd protection-from-light pattern which shades a field [**** / right above / of said mask / or directly under / again / as the protection-from-light pattern of the above 1st / almost] for the about 2, Z1, and 1st [of NA] protection-from-light pattern, and width of face restricts an exposure field by below Z1 and NA between a substrate and the 1st diffraction grating. Furthermore, it is desirable to scan and expose on a substrate the exposure field by which the limit was carried out [above-mentioned] if needed, or to expose, moving in the shape of a step. As for each [these] diffraction grating, it is desirable that it is a phase grating.

[0012] In addition, as for said diffraction grating, it is desirable to consider as a 1-dimensional diffraction grating, and to carry out aberration amendment of the wave aberration of said projection optical system so that it may become axial symmetry centering on the diameter of a direction vertical to the periodic direction of the above-mentioned diffraction grating on a pupil. Moreover, this invention demonstrates big effectiveness especially, when a periodic mold phase shift mask is used as a mask. Furthermore, it is

desirable to restrict the period and direction of a detailed pattern, or to amend a pattern configuration according to the period and direction of a diffraction grating, if needed. Moreover, if a refractive index n fills between the 1st diffraction grating and said substrates with a larger liquid than 1 and NA of said projection optical system is set as the range of 0.5<NA<n/2, formation of a still more detailed pattern will be attained.

[0013]

[Function] This invention will acquire effectiveness equivalent to increasing NA effectually by preparing a diffraction grating between the last element of a projection optical system, and a wafer, and enlarging the incident angle of the light beam which carries out incidence to a wafer side. However, only by preparing a diffraction grating between the lens-wafers of optical system conventionally simply, the diffracted lights which should originally be collected to one on the image surface are scattered all over the scattering location on the image surface, and playback of a mask pattern is difficult absolutely. Therefore, it is necessary to reconfigurate optical system so that an image faithful to the original mask pattern may be reproduced as a result of interference. And as for the viewpoint of practicability to such optical system, it is desirable that the conventional mask is moreover usable, without converting the conventional projection optical system greatly. This invention satisfies these demands so that it may state below.

[0014] In order to explain an operation of this invention, the principle of the image formation by this invention is explained as compared with a conventional method. The situation of the image formation at the time of illuminating a mask or a phase shift mask the case where it illuminates vertically respectively, and aslant, conventionally by the conventional projection exposure optical system is shown in drawing 2 a, b, c, and d for the again comparison with drawing 1 of the image formation in the optical system based on one gestalt of this invention. In any drawing, 2:1 cutback optical system, coherent illumination, and a 1-dimensional pattern were assumed, and paraxial image formation approximation was carried out.

[0015] First, when the vertical illuminator of the mask is usually conventionally carried out by optical system (drawing 2 a), it diffracts with the pattern on a mask, and the beam of light which passed the pupil 24 (inside of drawing 20) of a projection optical system 23 among the diffracted lights converges on the image surface 25, it interferes in the light 22 which carried out vertical incidence to the transparency mold mask 21, and it forms a pattern. Here, if the pattern period which gives the greatest angle of diffraction which can pass a pupil is defined as the resolution limit, the resolution limit will become lambda/(2NA) (however, NA=sin theta 0). Furthermore, if the periodic mold phase shift mask 26 is applied to this optical system, as shown in drawing 2 b, the zero-order diffracted light will disappear and the diffracted light will arise in the symmetry to an optical axis 29 (alternate long and short dash line in drawing). For this reason, the greatest angle of diffraction which can pass a pupil becomes twice, and the resolution limit improves to lambda/(4NA).

[0016] moreover -- if slanting lighting is conventionally applied to optical system (it was assumed that the zero-order light 27 of the mask diffracted light passed through the left end of ****** since it was easy, drawing 2 c and) -- the inside of the mask diffracted light -- a core [light / zero-order] -- carrying out -- positive/negative -- only a single-sided component (drawing +primary light 28) with one of angle of diffractions passes a pupil, and converges on the image surface. Since the diffracted light which has a twice [in the case of vertical incidence] as many angle of diffraction as this can pass a pupil, the resolution limit becomes lambda/(4NA) too. However, in order to use only one side of a diffraction spectrum, the resolution of an isolated pattern is not different from the case of a vertical illuminator, and has the problem of contrast falling also in the case of a periodic pattern. Furthermore, since two or more diffracted lights cannot pass a pupil if a mask is changed into the periodic mold phase shift mask 26, a pattern is not resolved (drawing 2 d).

[0017] Next, the image formation in the optical system based on one gestalt of this invention is shown in drawing 1 . In the conventional optical system of drawing 2 , a diffraction grating A and a diffraction grating B are inserted between a mask 1 and a projection optical system 2, and, as for it, the optical system of drawing 1 inserts a diffraction grating C between a projection optical system 2 and a wafer 4 again. Here, let both the diffraction gratings A, B, and C be phase gratings.

[0018] The light R which carried out vertical incidence to the mask 1 is diffracted by the zero-order diffracted light R0, the +primary diffracted light R1, and -primary diffracted-light R1' in respect of a mask. the zero-order light R0 should reach the point A0 on a diffraction grating A, and the light diffracted in the -primary direction there should pass the left end of a pupil 3 (inside of drawing 5), after being diffracted in the +primary direction the point B0 on a diffraction grating B -- it diffracts in the primary [**] direction the point C0 on a diffraction grating C -- having -- an each image surface top -- two points are given to Q and P.

Moreover, the +primary diffracted light R1 reaches the point A1 on a diffraction grating A, and after the light diffracted in the -primary direction there is diffracted in the +primary direction the point B1 on a diffraction grating B, it is diffracted in the primary [**] direction the point C1 on a diffraction grating C through the right end of a pupil 3, and reaches the points Q and P on the image surface too. on the other hand -- a point -- A -- zero -- + -- one -- order -- a direction -- diffracting -- having had -- zero-order -- light -- R -- zero -- ' - one -- order -- the diffracted light -- R -- one -- ' -- receiving -- an optical path -- the above-mentioned optical path and above-mentioned optical axis 6 (alternate long and short dash line in drawing) of two beams of light -- receiving -- the symmetry -- becoming . That is, both are eventually diffracted in the primary [**] direction the point C0 on a diffraction grating C, and reach the point P on the image surface, and Q'. Therefore, three beams of light, the zero-order light diffracted with the mask and the primary [+] - primary beam of light, cross at P points. This [depend / on a mask angle of diffraction] is clear. Therefore, at Point P, a diffraction figure is reproduced faithfully.
[0019] Since the diffracted light with a twice as many angle of diffraction as this can pass a pupil using the optical system which has the same NA and a scale factor compared with a conventional method (drawing 2 a), the effectiveness same with having doubled NA two substantially is acquired. moreover -- slanting lighting (drawing 2 b) -- a core [light / zero-order] -- carrying out -- positive/negative -- either -- since the diffracted light of both sides is reproducible by this invention in the image surface to only diffracted light of one of the two being reproducible in the image surface, with slanting lighting, the improvement in resolution of the difficult isolated pattern is possible, and big contrast can be acquired to a periodic pattern. Furthermore, if a periodic mold phase shift mask is applied to this optical system (drawing 3 a), as a result of +primary light R+ and -primary light R- which the zero-order diffracted light disappears and have a twice [usual] as many angle of diffraction as this interfering, the degree of minimum solution image becomes lambda/(8NA). This is the one half of lambda/(4NA) which is a theoretical limitation at the time of using a periodic mold phase shift mask and slanting lighting until now, and improvement in fast resolution of it is attained by this invention. Moreover, the situation of the image formation at the time of applying slanting lighting in this optical system is shown in drawing 3 b. With slanting lighting, it becomes possible to pass a pupil to diffracted-light R1" which has a big angle of diffraction only to one side, and resolution can be improved to the twice [a maximum of] (8NA), i.e., lambda/, at the time of a vertical illuminator. Moreover, if various illumination light from which a mask incident angle differs is used, the effectiveness of partial coherent illumination can be acquired completely similarly in optical system conventionally.
[0020] It is as follows when the principle of this invention is explained from the position of the fourier diffraction theory (drawing 4). By the following explanation, the scale factor of optical system shall consider 1 in a phase grid, and a diffraction grating shall consider only the about 1-dimensional primary [**] diffracted light. From the point P on the image surface, when a pupil 3 is seen through a diffraction grating C, a pupil is divided into two by diffraction and it is visible (drawing 4 a). In each pupil, the mask Fourier transform image which passes a pupil at an angle of the specification which exists respectively appears. On the other hand, considering a mask side, the light diffracted with the mask is diffracted by diffraction gratings A and B, and forms two or more mask Fourier transform images on a pupil. Among these, a certain thing which passed the pupil at an angle of specification can be seen in the pupil which was visible in the top (drawing 4 b). That is, in the case of drawing 4 , the fourier diffraction figure on the right of drawing 4 b appears in the pupil on the left-hand side of drawing 4 a, and the fourier diffraction figure on the left of drawing 4 b appears in the pupil on the right-hand side of drawing 4 a. At this time, conditions to reproduce an image correctly at Point P are the following two points.
[0021] (1) The spectrum of the same point on a mask should appear through two pupils.
[0022] (2) Two spectrums should connect continuously at the contact of two pupils.
[0023] It is necessary to enable it in other words to see one continuous spectrum through two or more pupils.

[0024] from an image -- seeing -- a diffraction grating C -- minding -- f' -- two or more shifted pupils -- visible -- the inside of each of that pupil -- diffraction gratings B and A -- minding -- too -- f" -- supposing two or more shifted fourier diffraction figures appear, amplitude distribution [of a true image] u (x) is expressed with a degree type.
[0025]
u(x) =F [sigmap(f-f') -sigmao (f-f")] -- f'=**SCf"=** (SA-SB-SC) -- here As for the Fourier transform and p (f), a pupil function and o (f) express [F[ ]] the sum to the order of diffraction from which a real space coordinate differs from f in a mask fourier diffraction figure and x, and sin (sine) of the angle of diffraction of diffraction gratings A, B, and C and sigma differ in a spatial-frequency coordinate, and SA, SB and SC.

Therefore, if SA=SB+SC, the term which is set to f"=0 and set [as opposed to / both / both f'=**SC(s)] to f"=0 can be acquired. That is, one spectrum o (f) can be seen through two pupils p (f'**SC). furthermore -- in order to obtain the image to a same-on mask point at Point P -- the distance between a mask side and diffraction gratings A and B and the distance between a diffraction grating C and the ideal image surface, and Each ZA, ZB, and ZC -- SAand(ZB-ZA) =SC- (ZB+ZC) -- then, it is good.

[0026] When the upper conditions are applied to the optical system of reduction percentage M:1 and the image side numerical aperture NA under paraxial approximation, it turns out that what is necessary is just to set up the distance ZA and ZB between the periods PA, PB, and PC of diffraction gratings A, B, and C, a mask side, and diffraction gratings A and B, and the distance ZC between a diffraction grating C and the ideal image surface almost as follows.

[0027] In order to acquire sufficient improvement effectiveness in resolution by this invention to a 1/PA=1/PB-1/(M-PC) (ZB-ZA)/PA=(ZB/M+M-ZC)/PC pan, considering as lambda/NA<=PC <=root2 and lambda/NA is desirable.

[0028] As for diffraction gratings A and B, it is desirable that it is a phase grating. When diffraction gratings A and B penetrate not a perfect phase grating but zero-order light, effectiveness, such as optical system and oblique incidence optical system, laps with the effectiveness of this approach conventionally which is inferior to definition from this approach. For this reason, there is a possibility that definition may deteriorate. On the other hand, even if a diffraction grating C is a phase modulation grid and it is an amplitude intensity modulation grid, it is not cared about. If the period of a diffraction grating C is quite small and the silicon oxide of a refractive index 1.5 is considered, the cross-section aspect ratio of a grid pattern will become about about one. In this case, it needs to be cautious of the scattering effect of the light in a pattern cross section. In the case of the diffraction grating which consists of a protection-from-light pattern, since thickness of a light-shielding film is made quite thinly, the effect of dispersion can be reduced. However, the direction which uses a phase modulation grid can make an exposure field large so that it may state later.

[0029] If a refractive index n fills the substrate side of a diffraction grating B with a larger liquid than 1 etc., sin will turn into1/n of the wavelength of this field, and an angle of diffraction. Then, if the period of a diffraction grating B is further made fine and an angle of diffraction is made equal to the case where a liquid is not filled, since only wavelength is set to 1/n, resolution will also improve to 1/n. Although the diffracted light with a more big angle of diffraction needs to increase the appearance mask lighting angle which can pass a pupil in a mask side, it becomes impossible in this case, for the diffracted light with a small angle of diffraction to pass a pupil at this time. Then, it is desirable to increase the path of a pupil according to this. This can also be put in another way as follows. When the refractive index between a diffraction grating B and a substrate is 1, the improvement in resolution is not obtained at all as for 0.5 or more in NA of a projection optical system used by this invention. sintheta> The angle of diffraction over the beam of light which carries out incidence to the diffraction grating B of periodic lambda/NA at an angle of [theta] 0.5 is for becoming 90 degrees or more, localizing on a diffraction-grating front face as an evanescent wave, and not getting across to a wafer. On the other hand, if the refractive index between a diffraction grating B and a substrate is set to n, angle-of-diffraction theta' of the light which carried out incidence at an angle of sin theta=NA to the diffraction grating B (it must be periodic lambda/NA in order for the zero-order light which passed through the edge of a pupil to carry out vertical incidence to a wafer) will become sintheta'=(lambda/PB+sintheta)/n=2 NA/n, and the conditions for being theta'<90 degree will be set to NA<n/2. That is, this invention is applicable to validity to the optical system of maximum NA=n / 2. Although immersion optical system generally needs a special optical design, when it applies to this invention as mentioned above, a special lens is not needed at all. Therefore, if between a diffraction grating B and substrates is filled with water (refractive index 1.3 [about]) and is exposed using an about 0.6 NA [which is usually used in the semi-conductor process] projection lens, effectiveness equivalent to having set NA to 1.2 substantially will be acquired. In this case, if a phase shift mask is used, the resolution of 0.1 micrometers or less will be obtained also on the wavelength (365nm) of i line of a mercury lamp. In addition, by this approach, since the incident angle of light in which it interferes near the wafer is very large, it depends for the image formation engine performance in the polarization condition of light strongly. Generally, the light in which an electric field vector has a polarization condition vertical to the plane of incidence of light is more desirable when forming the image of high contrast.

[0030] All the above arguments need to assume paraxial approximation, need to set the refractive index of the substrate of a diffraction grating to 1, and need to take into consideration strictly actually the effectiveness of the refractive index of the substrate of a diffraction grating, and the effect of the aberration

produced by the diffraction grating. For this reason, the installation location of each diffraction grating etc. may be changed a little. It cannot be overemphasized that it is desirable to make it in agreement in sufficient precision as for the periodic direction of the pattern of two or more diffraction gratings.
[0031] Next, four points are described about the point which it should be careful of in this invention.
[0032] Generally an exposure field is conventionally restricted to the 1st compared with the exposing method by this optical system. Two beams of light cross also in the point Q on the image surface, and Q', it interferes mutually, and an image is formed so that drawing 1 may show. This image is an image of the false produced in the location which should be formed essentially, and out of which it does not come, and, generally is not desirable. In order to avoid this, it is desirable to form the protection-from-light mask 52 in right above [of the image surface 51] (between a wafer and diffraction gratings C), and to intercept the image of these falses, as shown in drawing 5 a. A diffraction grating C and the protection-from-light mask 52 can be formed in both sides of the same quartz substrate 53 as shown in drawing. (You may form on a separate substrate.) preparing similarly this, simultaneously the masking blade which shades the above-mentioned protection-from-light mask and a field [**** / almost] in right above [of a mask], or directly under again etc. -- carrying out -- a mask lighting field -- the above -- restricting to a field [****] is desirable. The exposure field which can be imprinted by one exposure is a field equivalent to the distance (about 2 and NA-ZB) between a true image (P points) and a fake image (Q points), repeats the twice of the above-mentioned distance as a period, and appears. Therefore, when narrower than the area which wants to expose the field which can be exposed, the thing which were shown in drawing 5 b and for which an exposure field is scanned on a wafer is [like] desirable. Under the present circumstances, if the reduction percentage of optical system is M:1, it cannot be overemphasized that it is desirable to also set strictly the ratio of mask scan speed and wafer scan speed to M:1. About the approach of carrying out the synchronous scan of these exposure field on a mask and a wafer, the approach used with the existing aligner can be used as it is. On the other hand, when larger than the area which wants to expose the field which can be exposed (i.e., when the distance between a true image and a fake image covers the chip which is one piece), it can expose, without scanning. The width of face of one exposure field increases, so that exposure area size is decided by the installation location of a diffraction grating B and a diffraction grating B is separated from the image surface. However, since the width of face of the field which cannot be imprinted also increases simultaneously, both rate does not change as [about 1:1]. In order to eliminate the effect of a fake image, as for the width of face W of an exposure-on wafer field, considering as W<=NA-ZB is desirable. Moreover, when an amplitude intensity modulation grid is used for a diffraction grating B, in order that the zero-order diffracted light of a grid may form the image of another false in the midpoint of a true image and a fake image, when an exposure field is a phase grating, it becomes half mostly.
[0033] Generally by this approach, exposure reinforcement falls to the 2nd. Only the light of the specific order of diffraction is used for the beam of light which carries out image formation on a wafer by this approach among the beams of light diffracted by the diffraction grating inserted into optical system. Therefore, the optical reinforcement which contributes to exposure whenever it passes a diffraction grating will fall. Moreover, having restricted the exposure field on a mask and a wafer, as stated in the top also causes throughput lowering. For this reason, it is desirable to cope with it using resist ingredients, such as a chemistry multiplier system resist with high sensibility which uses the light source with fully strong reinforcement by this approach, etc.
[0034] As pre- explanation showed [3rd], in addition to the desirable diffraction figure of f''=0, on a pupil, the Fourier transform image which shifted only f''=**2 (SA+SB) arises. This means that the high order spectrum of a mask pattern laps with a low spatial-frequency field substantially, and, generally is not desirable. In order to avoid this in the optical system of drawing 1 , it is PA<=1/(1-2 and NA/M). Then, it is good. In this case, it is because the diffracted light (equivalent to the dotted line emitted out of [A1] drawing 1) of the +primary direction by the diffraction grating A to the diffracted light (inside R1 of drawing 1) diffracted by angle-of-diffraction 2 and NA/M with the mask cannot exist.
[0035] By the optical system of this invention, it needs to be [4th] cautious of the aberration accompanying diffraction-grating installation. The aberration generated by the diffraction grating is explained using drawing 6 . The beam of light after mask passage assumes that it is in a field including the periodic direction of an optical axis and a diffraction grating (for example, a 1-dimensional pattern and coherent illumination). In order for the optical system of drawing 6 a to be non-aberration, the difference of each optical path length of OX1X2X3I, OY1Y2Y3I, and OZ1Z2Z3I must be 0. However, if an optical-path-length difference is among these, this will serve as aberration. If it assumes that a projection optical system is the ideal optical system of aberration 0, the difference of OX1X2+X3I, OY1Y2+Y3I, and OZ1Z2+Z3I will turn into

aberration from X2X3=Y2Y3=Z2Z3 here. If the wave aberration of an optical path which results in OZ1Z2Z3I from OX1X2X3I which crosses the diameter of a pupil is plotted to the pupil radius coordinate s standardized on the basis of OY1Y2Y3I, it will become like the continuous line of drawing 6 b. It turns out that aberration w+ (s) to the beam of light which has the include angle of + to a mask passage backward optical axis generally becomes unsymmetrical on a pupil. Aberration w-(s) to the beam of light which has the include angle of - to an optical axis similarly becomes the symmetry from the symmetric property of optical system considering w+ (s) and a pupil as a core. In this invention, since it is necessary to make the light diffracted in the direction of +, and the light diffracted in the direction of - interfere on a wafer simultaneously, it is necessary to amend the aberration to both simultaneously. However, since the pupil top aberration over the light diffracted in the direction of + and the direction of - is not in agreement so that drawing 6 b may show, it becomes difficult theoretically to amend these by the projection optical system simultaneously. Therefore, as for such aberration, it is desirable to amend between a mask and a projection optical system or between a wafer and a substrate. Generally this can be performed by the following approaches.

[0036] If w+ (s) and w-(s) is equal, it is possible to amend this by the projection optical system. then -- delta -- w -- (-- s --) -- = -- {-- w -- + -- (-- s --) --} - {-- w - (-- s --) --} -- a pupil top (with drawing 6 - the range of 1<=s<=1) -- wavelength -- comparing -- the amount delta small enough -- stopping -- ****ing . On the other hand, deltaw** (s) is expressed as a function of the parameters xi (i= 1, 2, --), such as relative-position relation between the installation location of each diffraction grating, the thickness of the substrate supporting a period and a diffraction grating, a refractive index and a substrate, and a diffraction grating. Then, the range of the problem is -1<=s<=1, and it results in calculating xi which fills deltaw(s, xi) <delta. An example describes the example of actual optimization. Anyway, it can do in this way and a symmetrical form, then this symmetrical can be amended for the aberration over the beam of light which has the include angle of ** to a mask passage backward optical axis in a projection optical system on a pupil. Furthermore, it is more desirable if the aberration itself can fully be controlled by the approach described in the top.

[0037] As mentioned above, since it was easy, the 1-dimensional pattern was assumed as a mask pattern, but when a two-dimensional pattern exists actually or partial coherent illumination is used, the beam of light after mask passage is not settled in a field including the periodic direction of an optical axis and a diffraction grating, but tends toward various points on a pupil. In this case, what is necessary is to consider function deltaw(s, t) ={w+(s, t)}-{w-(s, t)} of the two-dimensional coordinate on a pupil (s, t), and just to calculate as deltaw, xi which fills deltaw(s, t, xi) <delta within a pupil surface. This means making w** (s, t) into the most symmetrical possible form to s= 0 on a pupil.

[0038] Furthermore, in order to acquire the effectiveness of this invention to all directions, it is possible to use each diffraction grating as a two-dimensional diffraction grating, as shown in drawing 7 a and b. In this case, the form of the pupil on appearance serves as symmetry 4 times. However, except for the case where NA of optical system is small, it is a little difficult to carry out aberration amendment simultaneously on a pupil to 2 sets of vertical pupils according to the situation described in the top mutually. For this reason, it is a little difficult to acquire the effectiveness of this invention equally to all directions on a mask, and it is more realistic to use a 1-dimensional diffraction grating like drawing 8 . Drawing 8 a, b, and c sees with three typical diffraction gratings, and is the upper pupil configurations. In drawing 8 a, substantial NA increases about twice to the pattern of x directions, but it decreases to the pattern of the direction of y. In drawing 8 b, to the pattern of x directions, substantial NA becomes root2 twice and is set to 1/root2 to the pattern of the direction of y. As for NA, in drawing 8 c, x and y both directions become root2 twice, but it is thought that it depends for the image formation engine performance [/ in addition to x and the direction of y] in the direction of a pattern remarkably. It is desirable to impose the limit by the direction on the layout rule of a pattern etc. on a mask in any case.

[0039] In order to abolish the pattern direction dependency of the image formation engine performance, the conditions of drawing 8 a, b, and c may be rotated 90 degrees respectively, for example, and multiplex exposure may be performed. When this is especially applied to drawing 8 c, an image equivalent to x and y both directions having doubled NA root2, without controlling pattern direction dependency [/ in addition to x and the direction of y], and sacrificing image contrast can be obtained. However, when rotating a diffraction grating 90 degrees, an aberration property is also rotated 90 degrees. Then, it is desirable to cope with to perform aberration amendment using a pupil filter and to rotate this 90 degrees with a diffraction grating etc. In addition, when aberration control is difficult, you may carry out preparing a slit filter in a pupil if needed etc.

[0040] As shown in drawing 3 , when perfect coherent illumination of the periodic mold phase shift mask is

carried out, the optical path of primary [**] light in which it interferes near the wafer is always symmetrical to an optical axis, and each optical path length is equal. Therefore, even if aberration amendment of the optical system is not carried out, detailed pattern formation is possible. That is, when using a periodic mold phase shift mask under perfect coherent illumination, a two-dimensional diffraction grating as shown in drawing 7 is usable, it does not depend in the direction of a pattern, but the effectiveness of a phase shift mask can be demonstrated to the maximum extent. What is necessary is to expose only a detailed period pattern by the above-mentioned approach, and just to expose other parts by the exposing method conventionally after that, in imprinting the mask pattern with which various patterns are intermingled.
[0041] Moreover, generally the above-mentioned aberration increases rapidly with the value of NA. For this reason, in about 0.1 to 0.2-NA optical system, it does not become a problem comparatively. Therefore, when applying to the aligner for large areas of low NA and a low scale factor, the soft-X-ray cutback projection aligner of a reflective mold, etc., various constraint which was described in the top is mitigated.
[0042] As mentioned above, this invention passes a pupil for right-and-left one side of the fourier diffraction figure centering on a zero-order diffracted-light line independently respectively, and it can be said that it is what compounds this by the image side. Although it is already applied to the optical microscope as this view itself is discussed by the above-mentioned reference, the configuration of optical system realizable on a cutback projection optical system was not devised in this until now. This invention is exactly what realized this skillfully in the reduced-projection-exposure system. That is, the optical system of drawing 1 prepares a diffraction grating between a projection optical system and a wafer, and it constitutes optical system so that an image faithful to the original mask pattern may be reproduced as a result of wafer side interference, while it enlarges the incident angle of the light beam which carries out incidence to a wafer side. This invention is applicable to various projection optical systems, such as dioptric system, catoptric system and these combination, cutback optical system, and actual size optical system. Also as the exposure approach in the case of exposing a mask pattern to up to a wafer using such optical system, it is applicable to both a package imprint, a scanning method step-and-repeat one a step a scan, etc. Moreover, this invention is purely based on geometrical optics-effectiveness so that more clearly than the above explanation. Therefore, the trouble which originates for [as / in the approach using the above-mentioned Moire fringe] EBANESSENTO Mitsutoshi is not produced. Moreover, since it can detach from a wafer, it can install and there is moreover also no need, such as a synchronous scan, a diffraction grating is easily realizable far.
[0043]
[Example]
(Example 1) Based on this invention, as the scanning mold KrF excimer laser projection aligner of NA=0.45, the light source wavelength of lambda= 248nm, and reduction percentage 4:1 was typically shown in drawing 9 , it converted. That is, the transparence quartz plate 103 which has a phase grating pattern was inserted in both sides between the masks 101 and projection optical systems 102 which were installed on the mask stage 100. Moreover, between the wafers 105 and projection optical systems 102 which were installed on the wafer stage (sample base) 104, the protection-from-light pattern and the transparence quartz plate 106 which already has a phase grating pattern on one side were inserted in one side so that a protection-from-light pattern side might meet a wafer. The protection-from-light pattern used with a width-of-face period [1mm period of 300 micrometers] Cr pattern, and the phase grating pattern as Si oxide-film pattern of periodic = lambda/NA. It is 4 times [by the side of a wafer] the period of the phase grating pattern on the mask side transparence quartz plate 103 of this. Si oxide-film thickness was set up so that the phase of the light which penetrated the film's existence section and the part not existing might shift 180 degrees. These patterns were formed like the so-called production process of a chromium loess phase shift mask using EB lithography. Moreover, the transparence quartz plate 108 which has width of face of 1.2mm and a periodic =4mm protection-from-light pattern was formed in the illumination-light study system 107 side of a mask. The protection-from-light field of the above-mentioned protection-from-light pattern was set up so that it might become a protection-from-light pattern on the wafer side transparence quartz plate 106, and conjugate.
[0044] Thickness, an installation location, etc. of the period of the phase grating of transparence quartz plate 103 both sides and each transparence quartz plate were optimized using the ray-tracing program optimization function so that the aberration on the projection optical system pupil in the semantics stated to the term of an operation might serve as axial symmetry. Furthermore, the aberration amendment filter 109 was inserted in the pupil posion of a projection optical system for aberration amendment symmetrical with the above-mentioned shaft. Here, the aberration amendment filter 109 amends the astigmatism of a direction mainly vertical to the periodic direction of the above-mentioned diffraction grating. In addition, each of

transparence quartz plates which have these diffraction gratings etc., and aberration amendment filters is exchangeable, and it enabled it to set them up for whether being Sumiya at a position. Moreover, in order to position a transparence quartz plate to accuracy, the electrode holder (not shown) of each quartz substrate has a jogging device (not shown), can measure the location of each quartz substrate, and can set this as a desired location. Furthermore, by acting as the monitor of the image by the autofocus monitor (not shown) which prepared on the wafer stage 104, it also made it possible to feed back a monitor result and to adjust the location of each quartz substrate so that the optimal image formation property might be acquired on the image surface. In addition, aberration amendment may be beforehand performed for the projection optical system itself to the above-mentioned diffraction grating, and it is unnecessary in an aberration amendment filter in this case. Exposure was performed carrying out the synchronous scan of a mask and the wafer. A stage control system 110 carries out the synchronous scan of a mask stage 100 and the wafer stage 104 with the velocity ratio of 4:1 respectively.

[0045] The mask which has the pattern of various dimensions containing a periodic mold phase shift pattern was imprinted to up to the chemistry multiplier system positive resist using the above-mentioned aligner. As a result of performing a development predetermined [after exposure] and observing under a scanning electron ray microscope, the resist pattern with a dimension of 90nm (period of 180nm) has been formed with the periodic mold phase shift mask to the periodic direction (x directions) of the above-mentioned phase grating. On the other hand, the resolution of a direction (the direction of y) vertical to the above-mentioned direction was dimension extent of 140nm (period of 280nm) using the phase shift mask. Then, when the phase grating of the three above-mentioned sheets and the aberration amendment filter were rotated 90 degrees, the same mask was exposed next and the resist pattern was formed, the resolution to x directions and the direction of y was reversed.

[0046] In addition, although, as for the upper example, a period, an installation location, etc. of the class of the class of optical system, NA, light source wavelength, reduction percentage, a resist, and mask pattern, a dimension and a diffraction grating, and a protection-from-light pattern are limited extremely, these various conditions can be variously changed within limits which are not contrary to the main point of this invention.

[0047] (Example 2) Next, the example which optimized optical system is shown so that the effect of the aberration accompanying diffraction-grating installation may serve as min. In the optical system of drawing 10 , the mask side of a projection optical system where mask side [where O and I introduced the diffraction grating / of optical system], image surface, sigma, and sigma' does not introduce a diffraction grating, the image surface, and hi (i=1-6) show the distance in drawing. The protection-from-light pattern of diffraction gratings A, B, and C and wafer right above was formed in both sides of a transparence quartz substrate like the example 1. At this time, transverse aberration w** (s) to the beam of light which has the include angle of ** to an optical axis after mask passage is expressed as follows as a function of the normalization pupil radius coordinate s.

[0048]

w**(s) =wu** (s) +ws** (s) wu**(s) =C1h1+C2(s1) h2+C5h5 -- +C6h6 ws**(s) =C3h3 -- +C4h4 C1=tan [(second**s0) /M]/M and C2=tan[**(s1/n)-(second**s0)/(nM)]/M -- C3=tan[s/M]/M and C4= -- tan (s) C5=tan[(second**s0) /n] C6=tan (second**s0) -- here, wu expresses an unsymmetrical component and a component with symmetrical ws to s= 0 on a pupil. However, they are s0=NA and s1= lambda/PA. When s0 (NA), the cutback scale factor M, and the refractive index n of a transparence quartz substrate are made into the value of a system proper, a top type contains seven optimization parameters, and hi (i=1-6) and s1. Then, these values were optimized wu** and by imposing seven constraints that aberration should be made min to ws** (s) (s). An example of an optimization result to some NA(s) is shown in a table 1. However, aberration was expressed with the wave aberration which makes h5/lambda a unit.

[0049]

[A table 1]

表1

NA	0.1	0.2	0.3	0.4
h_1/h_5	17.352	16.167	14.263	11.343
h_2/h_5	0.529	0.995	1.343	1.507
h_3/h_5	24.014	22.800	20.137	14.819
h_4/h_5	0.368	0.485	0.652	0.920
h_6/h_5	0.01	0.01	0.01	0.01
s_1	1.225	1.259	1.300	1.349
$w_{max}(s)$	5×10^{-9}	3×10^{-7}	4×10^{-6}	5×10^{-6}
$w^{u}_{max}(s)$	1×10^{-12}	1×10^{-9}	2×10^{-7}	1×10^{-5}

$w^{u}_{max}(s) = \max[w_+(s) - w_-(s)]$

$s_1 = n\lambda/P_A$

[0050] As shown in a table, it was possible to fully have suppressed aberration also in NA=0.4. Same optimization can be performed to various arrangement, when diffraction gratings A and B are respectively formed on another transparence substrate. Furthermore, still severer aberration conditions can be satisfied by increasing the parameter of optimization by introducing a new transparence substrate and a new diffraction grating.
[0051] (Example 3) Next, the example which created DRAM of 0.1-micrometer design rule is described using the aligner shown in the example 1. Drawing 11 shows the making process of the above-mentioned device focusing on an exposure process.
[0052] First, an isolation 202 and the gate 203 were formed on the Si substrate 201 in which the well etc. was formed (not shown) (drawing 11 a). The isolation and the gate pattern were exposed with the aligner shown in the example 1 using the periodic mold phase shift mask. Here, since it was predicted that the part into which a pattern configuration is distorted in the periphery of a periodic pattern by simulation arises, the mask for removing this garbage was prepared. After piling up and exposing the above-mentioned mask using an aligner to the same resist film as what performed the above-mentioned exposure conventionally, negatives were developed, and the part which is not desirable was removed on the circuit engine performance. In addition, you may cope with it by ignoring in circuit, without removing the above-mentioned garbage.
[0053] Next, the capacitor 204 and the contact hole 205 were formed (drawing 11 b). The electron ray direct writing method was used for pattern exposure of a contact hole. Next, the 1st-layer wiring 206, a through hole (not shown), and the 2nd-layer wiring 207 were formed (drawing 11 c). The 1st-layer wiring (0.1micromL/S) was exposed using the aligner shown in the periodic mold phase shift mask and the example 1. However, it changed into what showed the direction and dimension of each diffraction grating to drawing 9 c here, this was rotated further 90 degrees, and multiplex exposure was performed. At this time, the aberration amendment filter 109 was also simultaneously rotated 90 degrees with the diffraction grating. 0.1micromL/S has been formed without direction dependency to wiring prolonged in both directions in every direction by this. Formation of a through hole used the electron ray direct writing method like the contact hole. Subsequent multilayer-interconnection patterns and final passivation patterns are designed with 0.2-micrometer rule, and were formed by the usual KrF excimer laser projection exposing method do not use this invention. In addition, it is not caught by what was used in the above-mentioned example about the structure of a device, an ingredient, etc., but can change.
[0054] (Example 4) Next, the example which applied this invention to the fabrication of distribution feedback mold (DFB) laser is described as another example of this invention. What converted the ArF excimer laser cutback projection aligner of NA0.5 like the example 1 was used for the aligner. In the making process of the conventional quarter-wave length shift DFB laser, the diffraction grating with a period of 140nm currently formed using the electron-beam-lithography method etc. was formed using the periodic mold phase shift mask and the above-mentioned aligner. It became possible to manufacture more the DFB laser which has by this the engine performance almost equivalent to what was produced using the electron-

beam-lithography method etc. for a short period of time.

[0055]

[Effect of the Invention] As mentioned above, when according to this invention light is irradiated through an illumination-light study system at a mask, image formation of the mask pattern is carried out to up to a substrate according to a projection optical system and a pattern is formed, While preparing a diffraction grating in the above-mentioned substrate and parallel between the above-mentioned substrate and the above-mentioned projection optical system So that the image of a mask pattern may be reproduced by interference of the light diffracted by the above-mentioned diffraction grating near the substrate side By establishing a diffraction grating or image formation optical system between a projection optical system and a mask or between a mask and an illumination-light study system, formation of the detailed pattern conventionally beyond the resolution limit of an aligner is attained. Specifically, effectiveness almost equivalent to having doubled [a maximum of] the NA substantially is acquired, without changing NA of a projection optical system. Without changing the fundamental configuration of the optical system of an aligner greatly thereby conventionally, the big exposure field and high resolution are acquired and manufacture of LSI of a dimension the class of 0.1 micrometers is attained using the cutback projection optical lithography suitable for mass production method.

[0056]

[Translation done.]

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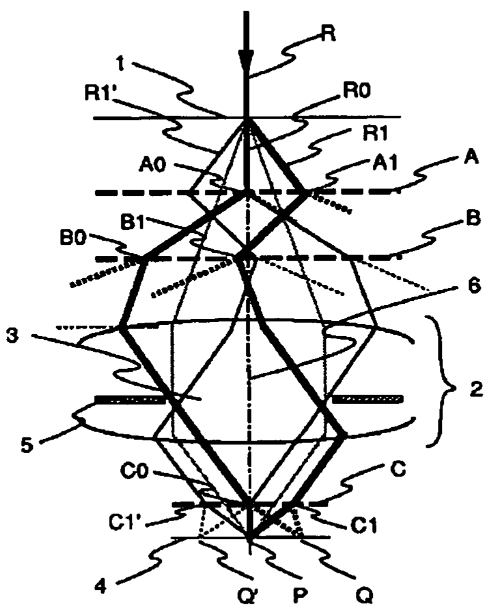
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

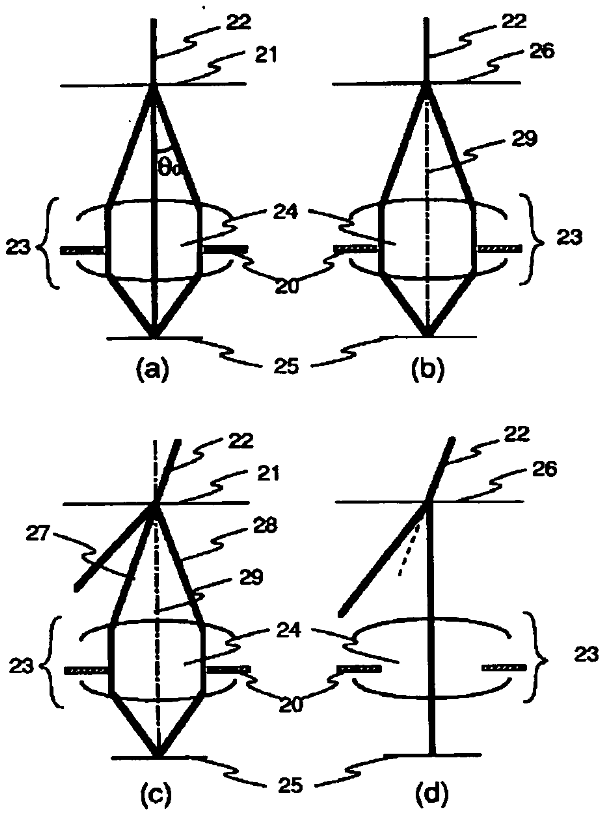
[Drawing 1]

図1



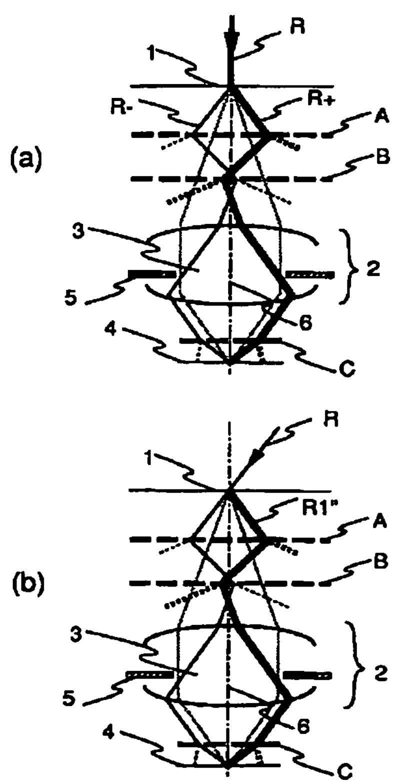
[Drawing 2]

図 2



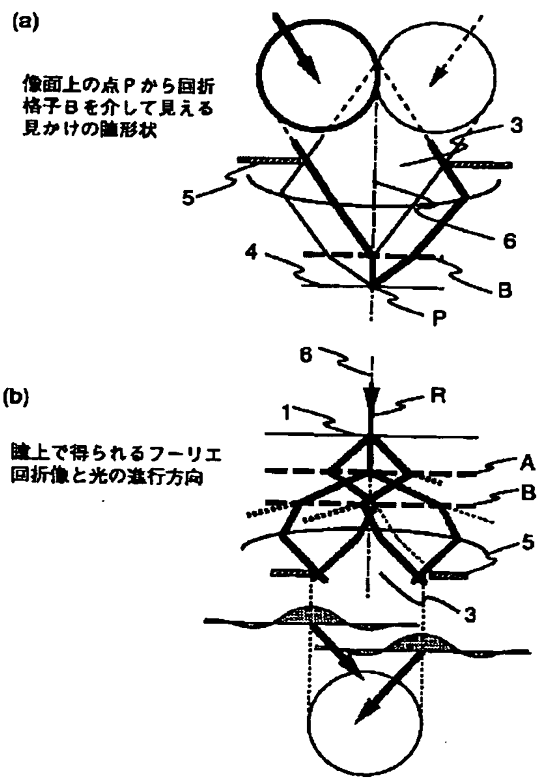
[Drawing 3]

図 3



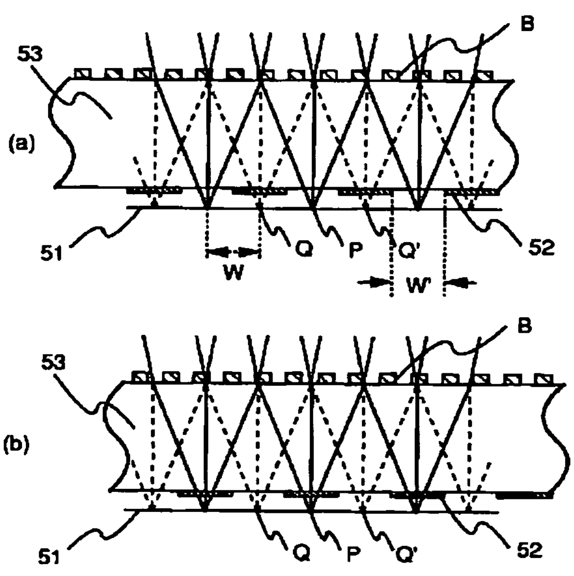
[Drawing 4]

図4



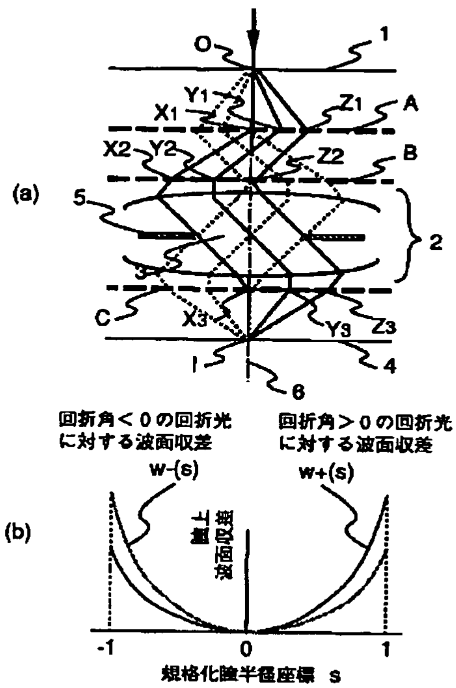
[Drawing 5]

図5



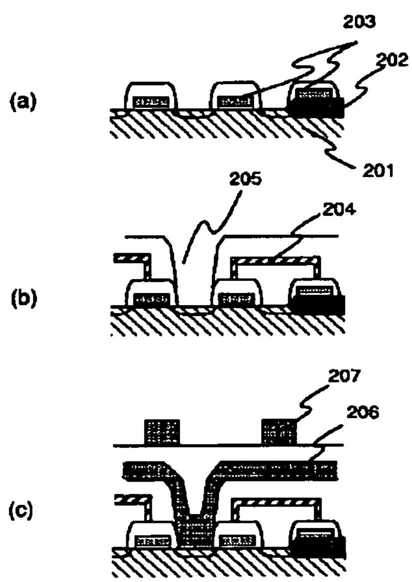
[Drawing 6]

図6



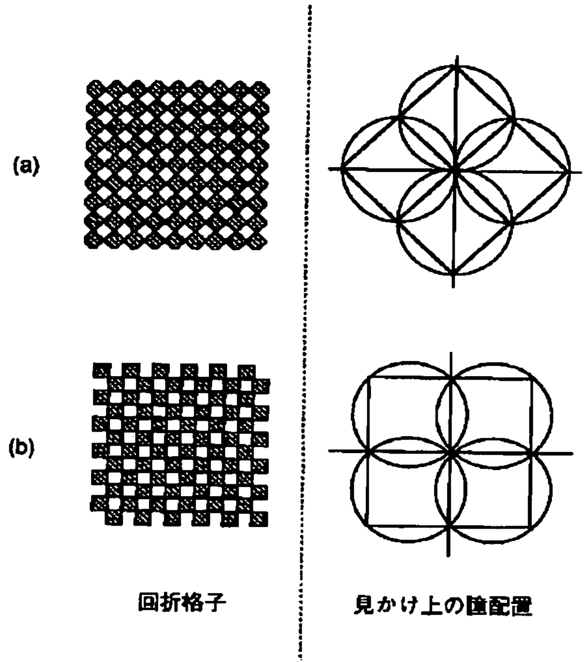
[Drawing 11]

図１１



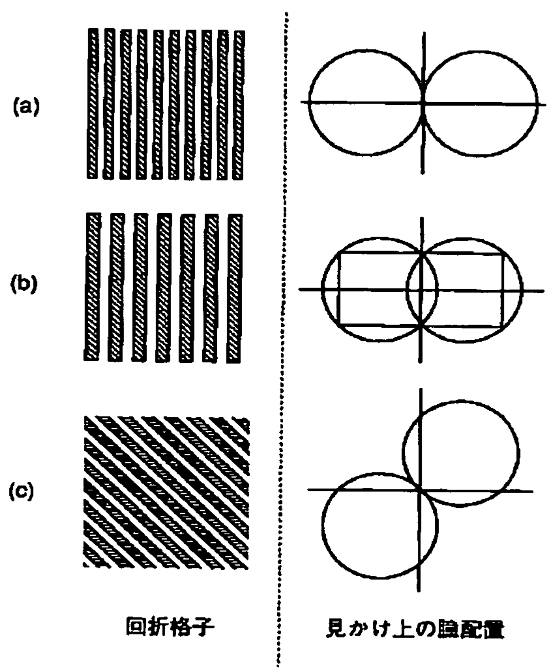
[Drawing 7]

図 7



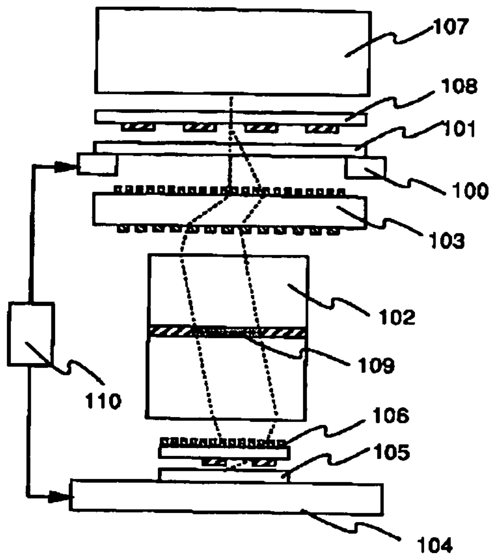
[Drawing 8]

図 8



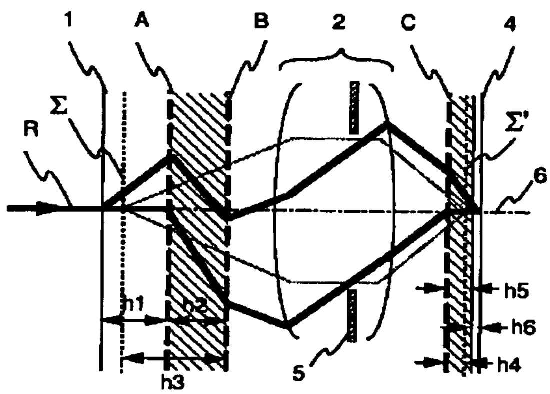
[Drawing 9]

図9



[Drawing 10]

図10



[Translation done.]